

Civilian Research Project Senior Service College Fellow

Improving Corrosion Prevention and Control in the Army

by

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The Army spends approximately 2.4 billion of dollars annually in corrosion prevention and corrective maintenance of tactical wheeled vehicles. Billions more are invested in the recruitment, training and retention of the manpower needed to utilize and support this equipment. The products of these investments and their material properties are at risk of degradation due to corrosion. This paper will analyze and determine what critical, effective and appropriate actions could be taken in order to improve the Army's performance on issues related to corrosion prevention and control programs on tactical wheeled vehicles. In addition, this paper will analyze the effectiveness of the Army Corrosion Prevention and Control Strategic Plan, its key elements, prevention initiatives, current training, education, budget constraints, statutes and future policy changes. Finally, this paper will provide recommendations on how to educate and integrate operators, maintainers and workforce on preventing corrosion. Decision makers will then be better prepared to determine allocation of strategic resources, prioritize policy initiatives and assess options needed to improve corrosion prevention on tactical wheeled vehicles.

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IMPROVING CORROSION PREVENTION AND CONTROL IN THE ARMY

I. BACKGROUND

Corrosion costs the Department of the Army (DA) approximately 6 billion dollars annually (2.4 billion on tactical wheeled vehicles alone).¹ In 2003, and in an attempt to minimize these costs, the Secretary of Defense directed DA to establish an office to develop and oversee policy and procedures for corrosion prevention and control.² Then in Fiscal Year (FY09) and through the National Defense Authorization Act (NDAA), the Assistant Secretary of the Army responsible for acquisition, logistics, and technology was required to designate a senior staff member as the Service corrosion control and prevention executive (CCPE) to oversee all activities management and technical awareness of corrosion prevention and control for equipment and infrastructure.³

Acknowledging that the Department of Defense (DOD) is already looking at budget cuts meant to save the federal government approximately 487 billion dollars over ten years, DA has been looking at changing business practices and drafting new policies to ensure the goals of improving and reducing corrosion on equipment (especially on tactical wheeled vehicles) are met.⁴ However, this is something very challenging since we have been at war for more than ten years. Besides, corrosion is a long-term issue that usually affects tactical wheeled vehicles operation some time after procurement. Moreover, corrosion prevention and control is a critical consideration in assuring the sustained performance, readiness, economical operation and service life of Army equipment. It requires active consideration in the materiel development, acquisition, fielding operation, and storage processes. Corrosion prevention and control

requires life cycle management planning and action in design, development testing, training, and maintenance.

II. LITERATURE REVIEW

A. Introduction

The term “corrosion” means the deterioration of a material or its properties due to a reaction of that material with its chemical environment.⁵ Others add and define the term “corrosion prevention and control” as the rigorous application of engineering design and analysis, quality assurance (QA), nondestructive inspection (NDI), manufacturing, operations, and support technologies to prevent the start of corrosion, avoid functional impairment due to corrosion, and define processes for the tracking and repair of corrosion problems.⁶ Others add the term “corrosion environment” to these definitions since most of DA equipment and facilities are composed of materials that are susceptible to oxidation, stress, surface wear and other chemical and environmental mechanisms that cause corrosion.⁷

Many Army forces operate world-wide in locations that produce varying corrosion related effects. These locations range from aggressive coastal or marine environments like Hawaii and Japan, where our forces battle the effects of humidity, temperature, and salt spray to caustic desert settings like Kuwait and Afghanistan, where wind-blown sand penetrates every crevice and erodes surface materials. Furthermore, the Army recognizes the insidious and pervasive effects corrosion has on equipment readiness, personal safety and the tremendous negative impact manifested in reduced availability, deteriorating performance and ever-increasing total ownership cost of war-fighting tactical wheeled vehicles.⁸

The fact is, corrosion has a significant impact on operational readiness and safety (both by itself and in conjunction with other damage phenomena), and its interactions with these factors should be considered during the conceptual design phase of tactical wheeled vehicles. National priorities dictate the need for extended service lives for Army tactical wheeled vehicles.⁹ History indicates the effects of corrosion increase with system age, which only amplifies the need to consider corrosion prevention as a primary design parameter.¹⁰ As a consequence, the original design should include the best materials and manufacturing processes. This means that Army tactical wheeled vehicles ought to be designed, produced, constructed, maintained and sustained to perform safely and reliably in diverse and extreme environments. Plus, consideration of operational and logistics capabilities (such as readiness, reliability, sustainability, and safety) are critical to ensure the effectiveness of tactical wheeled vehicles, and are usually accomplished during conceptual design, when the effects of corrosion on these capabilities should be addressed as well. Additionally, corrosion prevention control and mitigation ought to be considered during life-cycle cost tradeoffs. Further, it requires a workforce that is knowledgeable and skillful in the identification and management of corrosion.

B. Corrosion Prevention and Control Strategic Plan and Key Elements

According to DA, the purpose of this Corrosion Prevention and Control Strategic Plan is to articulate policies, strategies, objectives and plans that will ensure an effective, standardized, affordable Army-wide approach to preventing and controlling corrosion and its effects on military equipment.¹¹ A meaningful Army corrosion prevention and control (CPC) program will enable Army leadership to make conscious,

coordinated decisions to address corrosion issues with a more effective and efficient strategy. The CCPE believes that this approach has the potential to reduce the cost of corrosion by as much as 25%, largely by eliminating redundancies and shifting emphasis from corrective measures to preventive measures.¹²

For the strategic plan, the core of effective CPC can be described in five mutually supportive key elements. These five key elements are mentioned as define, prevent, predict, detect and mitigate, and form the foundation for this Strategic Plan.¹³ In addition, it contains a process called life cycle perspective which additionally includes some analyses and actions like requirements generation, design/prototype development, testing and evaluation, operation and sustainment.¹⁴

Definitions of the CPC Process Key Elements

- Define. Includes specific required user capabilities for CPC in terms of availability, safety and cost in equipment and infrastructure requirements documents. It identifies CPC performance attributes in acquisition and construction planning documents and requires CPC deliverables in contractual instruments (e.g., requests for proposal) such that suppliers clearly understand what the government wants delivered. It describes policies and procedures to ensure an effective and efficient CPC program and delineates targeted investments to develop improved requirements and metrics as necessary.¹⁵

- Prevent. Design equipment prototypes to prevent materials, parts, components, assemblies, subsystems and systems from corroding beyond defined CPC requirements, and modify designs based on data collected during prediction, detection and mitigation processes. It applies industry, academia, government and

military best practices for corrosion preventive design, including material, process and geometry selection and integration. It designs corrosion preventive maintenance and support procedures to avoid the onset of corrosion on fielded equipment. Moreover, it applies industry, academia, government and military best practices for corrosion preventive maintenance and support activities, including packaging, preservation, surface treatment, storage and dehumidification.¹⁶

- Predict. Predict the ability of equipment prototype designs to achieve defined CPC requirements within specified time periods, conditions and confidence levels. It applies industry, academia, government and military best practices for corrosion prediction, including modeling, simulation and accelerated testing.¹⁷

- Detect. It monitors the operating environment for conditions leading to corrosion. Identify the onset of corrosion at the earliest time possible on fielded equipment and infrastructure. Discriminate between the different forms of corrosion and their impacts. Evaluate the progression of discovered corrosion against defined CPC requirements, designed preventive measures and predicted performance. It supports condition-based maintenance of equipment. Apply industry, academia, government and military best practices for corrosion detection, including military and civilian training, data collection/storage, non-destructive inspection and sensors.¹⁸

- Mitigate. Mitigation uses data collected during detection processes to conduct focused corrosion mitigation activities on equipment and infrastructure to minimize impacts on availability, safety and cost. It stops the spread of cosmetic corrosion before it can lead to other forms of corrosion. Additionally, it restores corroded areas of equipment to ready status and responds to changing missions, operating environments

and other conditions that may lead to increased corrosion. Further, it applies industry, academia, government and military best practices for corrosion mitigation, including repair, corrective maintenance and supplemental preventive maintenance.¹⁹

CPC Process

The CPC processes (See figure 1 below) are depicted as a five-step cycle. The five- core CPC processes form an integrated system where each of them is supportive of and linked to the others four processes.²⁰

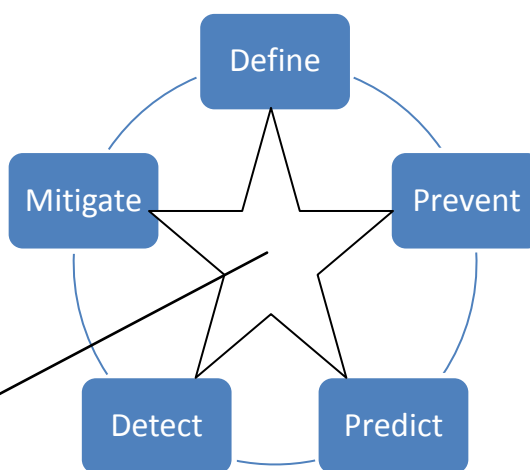


Figure1. CPC Processes²¹

Life Cycle Perspective

Although corrosion is most often observed late in the life cycle, i.e., during the operation and sustainment phases, it is not necessarily a result of neglect by users. CPC is a total life cycle issue that crosses all functional areas, meaning that users experience the end results of everything that has been done (or not done) earlier in the life cycle with respect to corrosion.²² While the Army remains engaged overseas in a major operation, war-fighters have less time to spend on CPC and therefore need more help than ever from other stakeholders in the tactical wheeled vehicles life cycle. Below

are just a few examples of some types of analyses and actions that should occur at various stages in tactical wheeled vehicles life cycle.

- Requirement Generation. The requirement generation develops measurable threshold, objective criteria for CPC that goes beyond the basic requirement for expected equipment or infrastructure service life. For tactical wheeled vehicles, this could be achieved as part of the Sustainment Key Performance Parameter (KPP) or as another performance attribute. These requirements are inserted into all appropriate documents. This also includes Initial Capabilities Documents, Requests for Proposal, Capabilities Development Documents and Capabilities Production Documents. Additionally, this includes the evaluation of equipment performance at pre-determined intervals throughout the life cycle to determine if the CPC requirements are truly measurable, valid, meaningful and achievable. This knowledge is used to refine the way CPC requirements are written for future systems and increments.²³ Decision makers (e.g., Program Managers) may still choose to trade off CPC in favor of other requirements. However, they will do so by conscious decision rather than by trading other attributes with hidden impacts on CPC.

- Design/Prototype Development. The Army utilizes subject matter experts on Corrosion Prevention Advisory Teams (CPATs) to review initial design/prototype development proposals and technical data from government and industry technology developers. These analyses identify potential corrosion risks based on literature searches, paper studies and institutional knowledge, and incorporate these risks into life cycle cost estimates and risk assessments during proposal evaluation.²⁴ This will make decision makers aware of corrosion risks and associated costs at the earliest possible

stage and minimize cost overruns and schedule delays caused by poor corrosion planning. It will also minimize the corrective actions necessary to control corrosion later in the life cycle.

- **Testing and Evaluation.** Testing and evaluation includes accelerated corrosion testing or predictive corrosion modeling in the Testing and Evaluation Master Plan for equipment. It verifies that the proposed design is capable of meeting CPC requirements and complete corrosion testing/modeling prior to production/construction. It is also used to evaluate results of corrosion testing/modeling to identify CPC deficiencies in proposed design. Also, it develops and implements design changes where technically and economically feasible to address corrosion prevention deficiencies prior to Low Rate Initial Production (LRIP) decision for equipment.²⁵ This will minimize the cost and burden associated with corrosion corrective actions later in the life cycle. In addition, this will allow users (e.g., commanders) to consciously plan, program and budget for CPC rather than absorbing it as a hidden cost during operation and maintenance.

- **Operation.** It analyzes potential impacts of environmental factors on fielded tactical wheeled vehicles and infrastructure in order to develop generic CPC procedures for incorporation into maintenance procedures (e.g., technical manuals and bulletins (TMs/TBs)) and site-specific storage procedures (e.g., location, shelter, dehumidification, etc.). Operation uses quality deficiency reports or similar mechanisms to identify specific corrosion issues with as much detail as possible and conducts periodic surveys of fielded wheeled tactical vehicles to determine corrosion status and adequacy of procedures. Also, it analyzes deficiency reports and survey data to identify

capability gaps and uses this knowledge to improve generic CPC procedures in TMs/TBs.²⁶ This will improve storage procedures, develop future production and identify technology opportunities for RDT&E. It also provides status updates back to the field until reported issues are resolved.

- **Sustainment.** Sustainment monitors corrosion status of equipment and infrastructure to support condition-based maintenance decisions. It makes a distinction between maintenance actions that are truly CPC related (e.g. metal surfaces that were degraded by galvanic corrosion) versus other similar actions that are not CPC-related (e.g. metal surfaces that were degraded by mechanical wear and abrasion). Likewise it is used to identify systemic corrosion drivers and provide feedback to DA-G4, Army Materiel Command (AMC), Research, Development, & Engineering Command (RDECOM), Program Managers, U.S. Army Training and Doctrine Command (TRADOC), Program Managers and U.S. Army Forces Command (FORSCOM) for tactical wheeled vehicles and the Installation Management Command (IMCOM) for facilities. TRADOC can prevent the same issues on future systems by incorporating the data into Concepts of Operations and Materiel requirements. Program Managers can prevent the same issues in new production runs of the same systems by incorporating the data into ECPs.²⁷ FORSCOM can mitigate the impacts of the issues on fielded systems by incorporating the data into operations and maintenance procedures. IMCOM can mitigate the impacts of the issues on existing facilities by incorporating the data into operations and maintenance procedures.

C. Corrosion Prevention and Control Initiatives

Currently, the Army CCPE is establishing several initiatives in order to improve corrosion prevention and control. For instance, the Army CCPE is also encouraging the tactical wheeled vehicle maintenance community to work together even more closely, since this is vital for effectively preventing corrosion.²⁸ In addition, the Army initiated a Silica-Based Chemical Agent Resistance Coating (CARC) Replacement for the tactical wheeled vehicles.²⁹ The replacement will strengthen the quality of topcoats, to have greater mar resistance and flexibility, resulting in better color and gloss retention and an overall longer life-cycle. Beyond that, multiple Controlled Humidity Protection systems were installed on Large Area Maintenance Shelters (LAMS) in some Army installations.³⁰ Under this project, dehumidified air is pumped into LAMS or equipment to reduce the rate of corrosion. The goal is to significantly reduce operational tempo cost and increase effectiveness.



Figure 2. Large Area Maintenance Shelters

For instance, at Fort Hood, the National Defense Center for Environmental Excellence (NDCEE) has designed, built, and demonstrated a prototype automatic

Corrosion Prevention and Control System for Army tactical vehicles.³¹ These efforts were used to optimize the final facility design and processing variables, allowing formal specifications and operating procedures to be generated. The findings from the portable automated system are being applied to construct and operate new corrosion inhibitor application facilities at U.S. Army shipping locations, tactical wheeled vehicles maintenance facilities, and depots.³² Besides the portable unit, the NDCEE implemented a permanent, manual-application Corrosion Control Center (CCC) at Fort Hood. The permanent CCC processes dozens of vehicles daily.³³

Plus, the Army is providing CPC training support to the Army National Guard (ARNG) and Army Reserve, developing interactive multimedia instruction for corrosion control inspection on tactical wheeled vehicles, and creating stronger partnership with the National Association of Corrosion Engineers (NACE) in order to provide free corrosion refresher courses at various Army installations.³⁴ Other on-going initiatives are cost benefit analysis studies, the development of new tactical wheeled vehicle publications, Lean Six Sigma (Black Belt effort) incorporating corrosion technology demonstration project, and preparing congressionally directed annual reports.³⁵



Figure 3. Corrosion Prevention in tactical wheeled vehicles

D. Effectiveness of Corrosion Prevention and Control

Major commands, program offices, and research and development centers service-wide have been trying to make improvements in the methods and techniques for preventing corrosion. For example, durable coatings, composite materials, and cathodic protection are being incorporated to an increasing extent in the design of tactical wheeled vehicles to reduce corrosion-related maintenance.³⁶ Systems such as the Mine Resistance and Ambush Protection (MRAP) vehicle use composite materials and advanced protective coatings to increase corrosion resistance.³⁷ The Army estimates that as much as 25 to 35 percent of corrosion costs can be eliminated by using these and other corrosion prevention efforts, which would amount to billions of dollars in potential savings each year.³⁸ A recent report on total ownership costs of tactical wheel vehicles discusses some of the approaches the Army is using to incorporate maintenance reduction techniques, including corrosion mitigation, into the design and development of new systems.³⁹

However, many Army commands' tactical wheeled vehicles face the risk of degradation due to ineffective corrosion prevention and control programs. For example, supported units of the 10thSupport Group located in Okinawa, Japan indicated they had recently experienced complete system losses due to corrosion.⁴⁰ The units claim that they are engaged in a continuous battle of detecting, repairing, treating, and preventing, corrosion related issues but the Army plan lacks specific performance measures to track the progress of corrosion mitigation efforts.⁴¹ Moreover, the 8thTheater Support Command, in conjunction with the 10thSupport Group, requested the Army Materiel Lessons Learned Analysis (AMLLA) to conduct a review and assessment of the

operating environment and conditions units and equipment were subjected to, review the maintenance and corrosion prevention procedures, corrosion prevention program, document observations and develop recommendations for potential improvements.⁴²

The AMLLA review and assessment in Okinawa found some issues that needed rapid improvement:

- Issue: Only unit equipment that was physically present was inducted and serviced.
 - a) Unit equipment inducted into the CPAC program was managed by contracted CPAC personnel and not by the owning unit.
 - b) Unit equipment was inducted by CPAC personnel physically walking unit motor pools and annotating the serial number of each vehicle; if the equipment was not present it was never inducted
 - c) When new serial numbers were found, equipment not previously inducted was then inducted into the CPAC program, however, equipment was not reconciled against unit property books; therefore, there was no guarantee that each piece of unit equipment was entered into the program.⁴³

AMLLA personnel comments were that the equipment should be inducted using property book inventory rather than physical inventory, and any unaccounted for equipment annotated as to the vehicle's status and whereabouts.⁴⁴ The current process allowed opportunity for equipment to be overlooked for inspection, maintenance, and CPC treatment. They also added that by using property books, all equipment is accounted for in the program and appropriate records can be maintained for deferred

inspection and maintenance.⁴⁵ These actions are where the weakest link exists for the possibility of equipment corrosion progressing and deteriorating.

- Issue: Contracted CPAC personnel perform operator and field level maintenance of stage 1 (general surface corrosion is present) and 2 (base metal is sound) corrosion.

- a) CPAC personnel perform unit field level corrosion maintenance

- b) Corrosion field level maintenance is a unit responsibility⁴⁶

AMLLA personnel comments were that the CPAC contracted personnel effectively controlled some progression of corrosion on serviced tactical wheel vehicles and maintained it in a relatively stable corrosion controlled state.⁴⁷ However, maintenance of stages 1 and 2 corrosion is doctrinally a unit responsibility and valuable resources are expended on conducting routine unit preventative maintenance and field level corrosion maintenance.⁴⁸

- Issue: Program Effectiveness Is Not Measured

As previously noted, the AMLLA personnel noted that there is substantial opportunity to achieve a deeper understanding of corrosion prevention through a structured data collection plan.⁴⁹ However, an additional benefit is measuring program effectiveness in terms of resource expenditures. In addition, the AMLAA assessed that even though some units were operating in a severely corrosive environment and relatively near to one another, few formal mechanisms existed to facilitate the exchange of corrosion information.⁵⁰ For example, in Hawaii, Army officials for the Reserve and National Guard and active units stated that they had limited knowledge of one another's corrosion control activities or the activities of other services.⁵¹



Figure 4. Geography of Okinawa.

- Subtropical climate
- Average temperatures approximately 10 degree higher than that of mainland Japan
- Long summers and short winters with minor differences between seasons
- Rainy season is from May through June with July through October considered Typhoon season
- Relative humidity fairly constant between 70 and 80%

Frustrated with all these corrosion issues, the tactical wheeled vehicle maintenance community has been sharing lessons learned and identified the “top 20” corrosion challenges across the Army. Based on the Army CCPE, these are the “top 20” challenges that can be solved through non-materiel paths, e.g., doctrine, training and leadership, or by materiel approaches, e.g., improved technologies.⁵² Below are the “top 20” corrosion challenges:

- Lack of command emphasis
- Soldiers incapable of recognizing corrosion indicators

- Soldiers lacked knowledge of corrosion mitigation techniques
- Units carrying too much Inventory for available storage
- Inadequate or insufficient inspection frequency
- Poor design of tactical wheeled vehicles
- Lack of military construction to improve storage facilities
- Improper type of storage for tactical wheeled vehicles
- OPTEMPO – inventory changed environments often
- Poor or out-of-date inventory control procedures
- Lack of training or inadequate training
- CARC paint poorly applied
- Sealants poorly applied
- Lack of external surface treatment
- Lack of effective corrosion control programs
- Lack of maintenance or inadequate maintenance
- Deficient field corrosion reporting and tracking
- Reduced readiness/availability
- Increased maintenance cost
- Increased cost of requisitions

E. Metrics for an effective corrosion prevention and control program

Identifying problems, implementing mitigation actions, and measuring changes are essential elements of program management.⁵³ Metrics that provide a quantified measurement of actions have to be an indispensable component of the Army's

corrosion strategy. This will allow the CPAC program manager and the various stakeholders to determine what works, what does not, and where to apply valuable resources if needed. Besides, these metrics in corrosion prevention and control need to be monitored against objectives and be specific, measurable, attainable, realistic, and timely. Among metric measures, the cost of corrosion is an essential metric in the determination of the impact of corrosion on tactical wheel vehicles. This was manifest in the December 2003, May 2005 and June 2007 Corrosion Reports to Congress that stated:

To quantify improvement an indispensable metric, an accepted baseline must be established. In addition, reliable corrosion cost estimates are necessary to identify areas that require aggressive action and to justify the expenditure of resources for prevention and mitigation strategy.⁵⁴

A methodology has been established to collect corrosion cost information from diverse maintenance and operational activities. The cost of corrosion data that has been obtained allows for the determination of primary cost drivers.⁵⁵ These cost drivers can then be used in identifying actionable corrosion mitigation projects and activities. To ensure that the Army does not miss opportunities for achieving long-term corrosion cost avoidances, an action plan is being developed for using the results of completed cost impact studies.⁵⁶

The total cost of corrosion for the Army is a key metric in assessing the impact of corrosion on the operating forces and to program funding for sustainment efforts to reduce this cost.⁵⁷ This metric information, once it has been collected and analyzed for the individual Army Commands, would afford a means to formulate specific recommendations for corrosion mitigation.

Metrics are also important to track the completion of key management activities in the Army's Corrosion Program. These metrics areas include: doctrine/policy; training; information dissemination; and project Return on Investment (ROI) validation.⁵⁸ Moreover, an essential requirement of the Department's Corrosion Program is to understand the impact of corrosion not only on cost, but also on readiness and safety.⁵⁹ While it has been historically recognized that corrosion has a significant negative impact on the Army, there has never been credible quantitative data that is actionable. Based on the Assistant Secretary of the Army for Acquisition Logistics and Technology's CCPE, the following objectives represent a starting point to guide Army Military, civilian and contractor personnel in the execution of CPC activities.⁶⁰

Objectives

- Develop requirements, policy and guidance documents that establish effective procedures for managing corrosion throughout the Army
- Complete revision of DA 750-59 (Army Corrosion Prevention and Control Program)
- Obtain information on the financial, safety and readiness impact of corrosion to include recurring updates required for trend analyses
- Formulation and training of sustainment workforce
- Influence new acquisition efforts, e.g., design, engineering, and material choices
- Influence corrosion mitigation of tactical wheel vehicles, e.g., monitoring and targeted remediation

- Explore the adequacy of available CPC education and training programs for potential use by the Army. Consideration will be given to how best to communicate this to the workforce
- The Army RDT&E community must identify and adapt commercial technologies or develop new technologies to meet Army CPC needs

Metrics

- Re-develop clearly defined goals, outcome-oriented objectives, and performance tools to measure progress toward achieving return on investment and net savings of prevention projects
- Review standardized methodologies for collecting corrosion-related cost, readiness, and safety data
- Distinguish meaningful training; communications & outreach; and science & technology
- Gather DA total cost of corrosion for use in program development
- DA G-4 needs to incorporate specific corrosion prevention for tactical wheel vehicles
- Use opportunities in the acquisition process to design corrosion prevention and mitigation
- Re-assess the corrosion health of fielded tactical wheel vehicles and take appropriate action to lessen degradation caused by corrosion

- Re-assess the need to establish a centralized requirement for CPC education and training (including certification requirements)
- Review budget request and program plan for developing, testing and evaluating CPC technologies for Army tactical wheel vehicles
- Re-establish procedures and milestones to hold major commands and program offices that manage tactical wheel vehicles and facilities accountable for achieving the strategic goals

III. REVIEW AND ANALYSIS

While the Army's current corrosion prevention and control strategy generally addresses the requirements in the congressional mandate, it falls short of representing a comprehensive plan needed to achieve improvement and successful results. An effective, results-oriented strategy identifies resources required to achieve its goals and outcome-based performance metrics that can measure progress toward achieving those goals. Without addressing and reviewing certain key elements, the strategy is unlikely to serve as an effective tool in preventing and mitigating corrosion and its effects on tactical wheel vehicles. These shortcomings could lead to the loss of billions of dollars in avoidable maintenance costs and the degradation of safety and readiness. It is also important to address and review three key elements that will reinforce the strategic plan. These key elements are funding and personnel resources, performance measures and milestones and policy guidance.⁶¹

- Funding and personnel resources. The strategy does not identify the exact amount of funding and personnel resources needed to implement the corrosion reduction plan in the near- or long-term. Officials in DA corrosion office said that

resource needs for corrosion prevention on tactical wheel vehicles were estimated at \$2.4 billion in fiscal years 2008-2009.⁶² The resources needed for fiscal year 2012-2013 and firm estimates have not being determined yet. However, preliminary projections made by the corrosion office indicated that DA wide corrosion reduction program would require about \$3 billion for fiscal years 2012 through 2016.⁶³ Additionally, DA reports stated that \$.6 billion in corrosion prevention facilities have been included in the budget.⁶⁴ Clearly and while the strategy calls for a mechanism that tries to ensure sustained, long-term funding, DA has been using a year-by-year funding approach that will not improve corrosion prevention and control.

- Performance measures and milestones. While the strategy includes some performance measures and milestones, they are not the results-oriented metrics needed to successfully monitor the program's progress. Even though DA completed its corrosion cost baseline study in March 2011 (because of limited funding), the plan did not address a complete and critically needed responsibility to major commands with regards to tactical wheeled vehicles.⁶⁵ Without accurate results-oriented metrics and a baseline, DA will not be in a sound position to establish cost-effective resource priorities or monitor progress toward corrosion reduction. In addition, DA has very little performance data, such as return on investment or annual savings, for any of their corrosion control initiatives. Even a report from the U.S. Government Accountability Office (GAO) in 2003 found that officials at the Army Center for Economic Analysis have not measured performance for the purpose of determining the return on investment for any corrosion control project for many years.⁶⁶

A GAO 2011 report noted that DA has multiple corrosion control efforts with

different policies, procedures, and funding channels that are not well coordinated with each other; as a result, opportunities for cost savings have been lost.⁶⁷ DA has established a central corrosion control office in response to the authorization act, but little oversight for corrosion control of equipment and infrastructure. Moreover, corrosion control and prevention responsibility largely falls on numerous commands, installations, and program offices to fund and implement projects.⁶⁸ Plus, each Army command also has separate corrosion control offices that are responsible for certain types of equipment, for example, tanks/automotive, aviation/missiles, armaments, and electronics.⁶⁹

- Policy guidance. While the strategy strengthens DA's policy guidance on corrosion prevention and mitigation, improvements can be made. However, the guidance does not extend a critical review to tactical wheeled vehicles and infrastructure programs, which go hand-in-hand on corrosion prevention and control.⁷⁰

IV. RECOMMENDATIONS

Current FEDEX Ground studies in Toledo, Ohio showed that practical, educational and technological changes have provided many new ways to prevent corrosion and the improved use of available corrosion management techniques, strategies, and best practices.⁷¹ FEDEX Ground corrosion strategies have been very successful and DA can learn from this in order to achieve better corrosion management, and preventive approaches in non-technical and technical areas. These corrosion prevention best practices include: (one) increase awareness of significant corrosion costs and potential cost-savings, (two) change the misconception that nothing can be done about corrosion, (three) improve policies, regulations, standards, and

management practices to increase corrosion cost-savings through sound corrosion management, (four) improve education and training of staff in the recognition of corrosion control, (five) implement advanced design practices for better corrosion management, (six) develop advanced life prediction and performance assessment methods, and (seven) improve corrosion technology through research, development, and implementation.⁷² In addition, there are significant barriers to both the development of advanced technologies for corrosion control and the implementation of those technological advances. In order to realize the savings from reduced costs of corrosion, changes are required in three areas: (one) the policy and management framework for effective corrosion control, (two) the science and technology of corrosion control, and (three) the technology transfer and implementation of effective corrosion control.⁷³ The policy and management framework is crucial because it governs the identification of priorities, the allocation of resources for technology development, and the operation of the system. Likewise, incorporating the latest corrosion strategies requires changes in industry management and government policies, as well as advances in science and technology.⁷⁴ It is necessary to engage a larger constituency comprised of the primary stakeholders, government and industry leaders, the general public, and consumers. A major challenge involves the dissemination of corrosion awareness and expertise that are currently scattered throughout government and industry organizations.

V. CONCLUSIONS

While corrosion management has slightly improved over the past several decades, the Army is still far from implementing optimal corrosion control practices. At present, DA does not systematically assess proposals for corrosion control projects,

related implementation issues, or the results of implemented projects, and it disseminates project results on a limited, ad hoc basis. Without a more systematic approach to corrosion problems, prevention efforts that have a high return on investment potential will likely continue to be under-resourced and continue to proceed at a slow pace. As a result, DA will continue to expend several billion dollars annually in avoidable costs and continue to incur a significant number of avoidable readiness and safety problems. Since corrosion that is left unmitigated only worsens with time, costs will likely increase as tactical wheeled vehicles age. Perhaps this is why the adage “pay now or pay more later” so appropriately describes the dilemma with which DA is repeatedly confronted when making difficult investment decisions. DA will continue to pay dearly for its limited corrosion prevention efforts and will be increasingly challenged to find the funds for ongoing operations, maintenance, and new tactical wheel vehicles acquisitions.

VI. ENDNOTES

¹ The United States Army Corrosion Prevention and Control Strategic Plan, 8 March 2011, pages 3-4, (accessed October 2011, <https://www.corrdefense.org/ReferenceLibrary.aspx?View=%7b651E9AE1%2dCBAF%2d477E%2dBBCE%2d259799637062%7d>).

² Bob Stump National Defense Authorization Act for Fiscal Year 2003, Congress directed that DOD develop a long-term corrosion strategy, including specific requirements, and that GAO assess it.

³ Section 903 of the Duncan Hunter NDAA for FY09 required the Assistant Secretary of the Army (Acquisition, Logistics and Technology) (ASA (ALT)) to designate a Corrosion Control and Prevention Executive (CCPE).

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⁵ P.J. Gellings, (1976). Introduction to corrosion prevention and control for engineers, Delft University Press, Rotterdam, Netherlands.

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⁷ Ibid, 2.

⁸ United States General Accounting Office (GAO), Defense Management: Opportunities Exist to Improve Implementation of DoD's Long-Term Corrosion Strategy," 7 July 2003, GAO Report number GAO-04-640.

⁹ GAO report number GAO-09-968R, 'Defense Acquisitions: Department of Defense Needs a Unified Strategy for Balancing Investments in Tactical Wheeled Vehicles', 28 September 2009.

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¹² Eric F. Herzberg, David A. Forman, Norman T. O'Meara, PhD, James C. Tran, The Annual Cost of Corrosion for Army Ground Tactical Vehicles, 2008-2009 Report, May 2009, page 1-6, (Accessed November 2011, http://corrdefense.nace.org/corrdefense_fall_2009/images/armycostofcorrosion.pdf)

¹³ The United States Army Corrosion Prevention and Control Strategic Plan, 8 March 2011, page 10, (accessed October 2011, <https://www.corrdefense.org/ReferenceLibrary.aspx?View=%7b651E9AE1%2dCBAF%2d477E%2dBBCE%2d259799637062%7d>).

¹⁴ Ibid, 10.

¹⁵ Ibid, 11.

¹⁶ Ibid, 11-12.

¹⁷ Department of Defense, Corrosion Prevention and Mitigation Strategic Plan, February 2011, (accessed October 10, 2011 <https://www.corrdefense.org/Key%20Documents/DoD%20Strategic%20Plan%20-%20February%202011.pdf>).

¹⁸ Ibid.

¹⁹ Ibid.

²⁰ Department of the Army, Office for Acquisition Logistics and Technology's Fiscal Year 2011 Annual Report on Corrosion Control and Prevention, 9 December 2011, Washington D.C..

²¹ Army Corrosion and Control Program Overview presented by Mr. William Pybus, Department of the Army Corrosion Control and Prevention Executive, November 2011, Washington, D.C.

²² The United States Army Corrosion Prevention and Control Strategic Plan, 8 March 2011, page 12, (accessed October 2011, <https://www.corrdefense.org/ReferenceLibrary.aspx?View=%7b651E9AE1%2dCBAF%2d477E%2dBBCE%2d259799637062%7d>).

²³ Ibid, 13.

²⁴ Ibid, 13-14.

²⁵ Ibid, 14.

²⁶ Department of Defense, Corrosion Prevention and Mitigation Strategic Plan, February 2011, (accessed October 10, 2011 <https://www.corrdefense.org/Key%20Documents/DoD%20Strategic%20Plan%20-%20February%202011.pdf>).

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²⁸ Army Corrosion and Control Program Overview presented by Mr. William Pybus, Department of the Army Corrosion Control and Prevention Executive, November 2011, Washington, D.C.

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⁴⁴ Ibid, 11.

⁴⁵ Mr. Chip Herrell, Operations Analyst for U.S. Army Japan, Presentation on Army Material Lessons Learned Analysis (AMLLA) Corrosion Assessment and Review, 2011, Okinawa Japan.

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⁴⁷ Ibid.

⁴⁸ Presentation on Army Material Lessons Learned Analysis (AMLLA) Corrosion Assessment at U.S. Army Japan, slide number 14, 2011, Okinawa Japan.

⁴⁹ Ibid, 15.

⁵⁰ Ibid.

⁵¹ United States General Accounting Office (GAO) Report to Congressional Committees, Defense Management: Opportunities to Reduce Corrosion Costs," 7 July 2003, GAO Report number GAO-03-753.

⁵² Army Corrosion and Control Program Overview presented by Mr. William Pybus, Department of the Army Corrosion Control and Prevention Executive, November 2011, Washington, D.C.

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<https://www.corrdefense.org/ReferenceLibrary.aspx?View=%7b651E9AE1%2dCBAF%2d477E%2dBBCE%2d259799637062%7d>).

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⁷³ Ibid.

⁷⁴ Ibid.

